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Management stand-alone hybrid renewable energy system based on wind and solar with battery storage

Gerenciamento de sistema híbrido autônomo de energia renovável baseado em energia eólica e solar com armazenamento de baterias

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Abdelhak Kechida
PhD in Electrical Engineering
Institution: Laboratory Applied Automation and Industrial Diagnostics at the Department of Electrical Engineering in the Faculty of Science and Technology
Address: Achour University of Djelfa, Algeria
E-mail: abdelhak.kechida@univ-djelfa.dz

Djamal Gozim
PhD in Electrical Engineering
Institution: Laboratory Applied Automation and Industrial Diagnostics at the Department of Electrical Engineering in the Faculty of Science and Technology
Address: Achour University of Djelfa, Algeria
E-mail: d.gozim@univ-djelfa.dz

Belgacem Toual
PhD in Electrical Engineering
Institution: Laboratory Applied Automation and Industrial Diagnostics at the Department of Electrical Engineering in the Faculty of Science and Technology
Address: Achour University of Djelfa, Algeria
E-mail: toualb@gmail.com

Redha Djamel Mohammedi
PhD in Electrical Engineering
Institution: Faculty of Science and Technology, University of Djelfa
Address: 17000 DZ, Algeria
E-mail: r.mohammedi@univ-djelfa.dz

Elbar Mohamed
PhD in Electrical Engineering
Institution: Faculty of Science and Technology, University of Djelfa
Address: 17000 DZ, Algeria
E-mail: m.elbar@univ-djelfa.dz

ABSTRACT

This paper describes the management of a standalone hybrid energy system (HES) based on two renewable sources. The sun, wind. and the battery supports the system. Solar panels and wind turbines (WT) connected with permanent magnet synchronous generators (PMSG) were used for power production. Power converters have been used together with control algorithms for efficient power management. The filters were used to dispose of the largest amount of harmonics in the inverter. The proposed model provides a strategy for managing energy under various generating conditions. In order to save energy for a fixed load. Proposed hybrid accession simulated with MATLAB/Simulink

Keywords: PV, WT, management, hybrid system, MPPT, inverter, converter, standalone, algorithm, PMSG, SOC,

RESUMO

Este artigo descreve o gerenciamento de um sistema de energia híbrido autônomo (HES) baseado em duas fontes renováveis. O sol, o vento. e a bateria suporta o sistema. Painéis solares e turbinas eólicas (WT) conectadas a geradores síncronos de ímã permanente (PMSG) foram utilizados para produção de energia. Conversores de energia têm sido usados em conjunto com algoritmos de controle para gerenciamento eficiente de energia. Os filtros foram utilizados para descartar a maior quantidade de harmônicos no inversor. O modelo proposto fornece uma estratégia para gerenciar energia sob diversas condições de geração. Para economizar energia para uma carga fixa. Proposta de acesso híbrido simulado com MATLAB/Simulink.

Palavras-chave: PV, WT, gerenciamento, sistema híbrido, MPPT, inversor, conversor, autônomo, algoritmo, PMSG, SOC.

1 INTRODUCTION

As the amount of fossil fuels decreases, their ever-increasing cost and the damage to the environment from their gases. Renewable energies will become necessary in the coming years. [1] [2] Because of the existence of many renewable energy sources such as wind, solar, marine, and hydroelectric. The most common is wind and solar energy, due to its sheer availability and ease of exploitation. [3] [4] Where many previous studies have shown that these sources can be exploited to form a hybrid system. So this system is the integration of two or more sources [5].

In the proposed system, two sources of renewable energy were combined, namely the wind and the sun. to create a hybrid system. [6] However, due to the intermittent availability and unpredictable nature of these two resources, the storage system is necessary to ensure the stability and continuity of service in this system. [7]

in order to manage hybrid systems well, researchers have used many different algorithms. In this regard, several literature controls were proposed by the researchers. In [1] energy management was used with the cuckoo research. Based on solar and wind energy, this management showed good results. But the problem in this work is the absence of a storage battery to ensure the continuous availability of energy. Or storing excess energy. In [2] a hybrid system was managed based on solar and wind energy and supported by a battery. The results were very good. But it was used on a weak scale. A single-phase inverter was used. It can only be used in weak energies.

the objective of this work is to manage a hybrid system based on renewable energies. It consists of two sources, wind and sun, Supported by a storage battery. These components are connected to a three-phase inverter to feed a 10 kW load. In order to manage this system, it is a matter of developing equations and algorithms for each element of the system to manage and control it. For this we entered different data related to wind speed and radiation. In order to produce less or more energy than the load needs.So that when the energy produced is more than the load requires, the remaining energy will be stored. And when the output is less than what the load requires, the energy will be drained from the battery. The load receives the required energy under all conditions and weather changes.

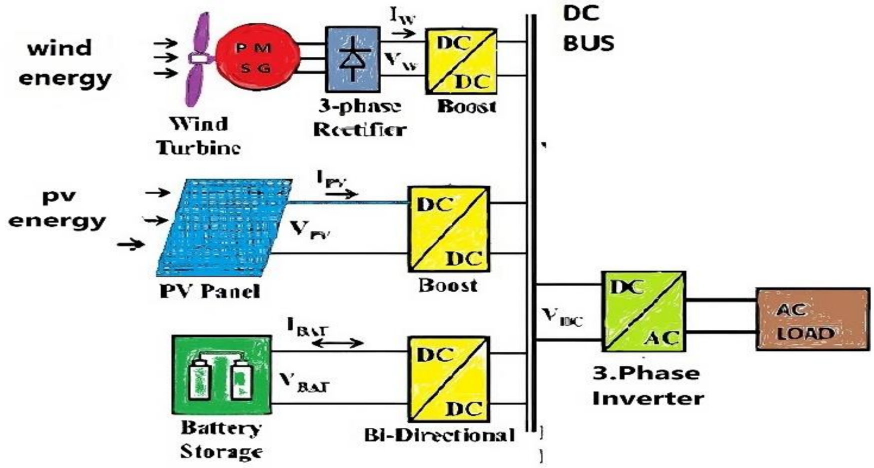
The MATLAB/Simulink program was used to simulate each component of the analyzed system, allowing the hybrid system to be examined and handled under various circumstances.

The study presented in this paper is divided as follows: In the second section, we review the hybrid system description by outlining how the system and its various parts function. We discuss energy management in this system in the third section. In the penultimate part, we review the simulation results and comment on them. And finally, the conclusion of this work in the last section

2 SYSTEM DESCRIPTION

The proposed system is shown in the figure. 1. It consists of three parts: 1. The renewable energy sources, solar and wind, are supported by an energy storage battery. The second part is the transformers connected to the aforementioned generating sources, which are DC_AC and DC-DC converters, to form a DC bus. The third part is the side inverter of the load and the three-phase load. The wind power to electric power conversion system is based on a turbine and (PMSG), and the solar power conversion system is made of solar panels operating at maximum power point tracking. When the energy produced by solar panels and wind turbines is greater than the load, the excess energy is stored in the battery. When the energy produced is less than the load, the role of the battery is to support the system by discharging the energy to ensure the stability of the system and the availability of energy in the load under various conditions.[3]

Figure 1: Components of the hybrid system wind solar battery



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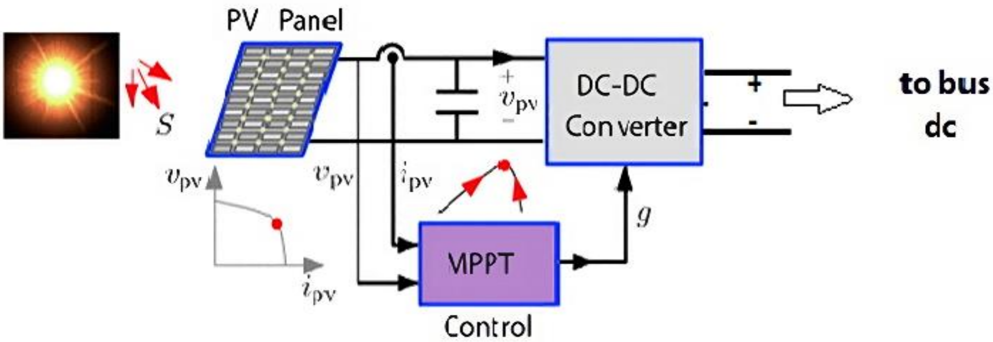
2.1 SOLAR ENERGY CONVERSION SYSTEM

Traditional The system (SECS) consists of a photovoltaic panel that converts solar radiation into electrical energy, a DC-DC converter, and a MPPT control device, as shown in the figure. 2. [8]

Figure 2: Model of a SECS



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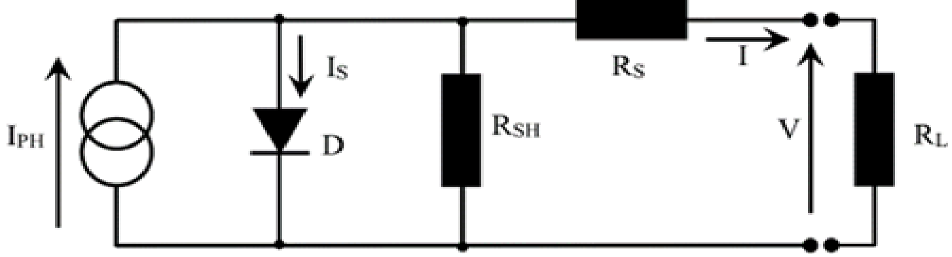
2.1.1 Model of a Photovoltaic Cell

$$\mathrm{Ic} = \mathrm{Iph} - \mathrm{Is}\left(\left(e^{\frac{q(Vc+Ic-Rs)}{n*K*Tck}} - 1\right)\right) - \frac{Vc+Ic*Rc}{Rsh} \quad (1)$$

$$Vco = \frac{m.K.Tck}{q}\ln\left(\frac{Iph}{Is}\right) \quad (2)$$

Figure 3: Equivalent circuit of the solar cell

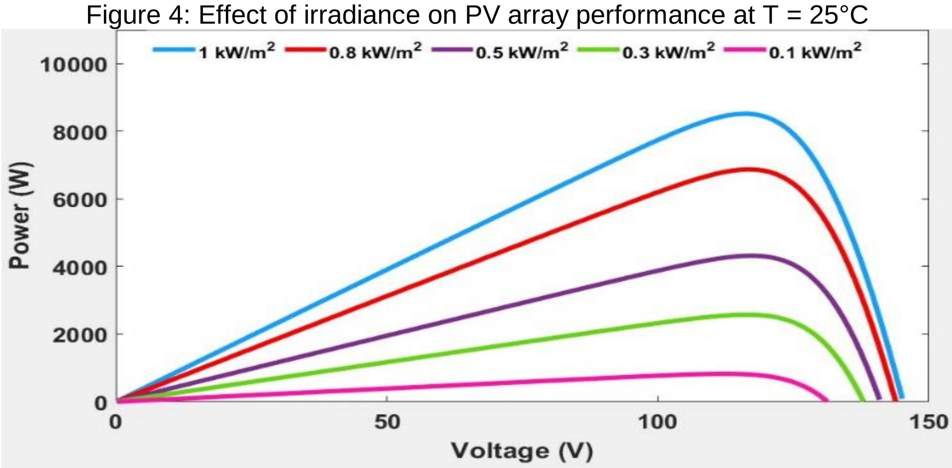


Source: Authors.

Ic : current cell (A)
Icc : cell short circuit current (A)
Iph : cell photocurrent (A)
Is : diode saturation current (A)
Vc : cell voltage (V)
Rs : series resistance (Ω)
Rsh : shunt resistor (Ω)
q = 1,6.10-19 (Cb)
k = 1,38.10-23 (J/K)
n : constant non-ideality of the diode

Figure (4) shows the PV characteristics of the solar panel and shows the characteristics for different values of radiation ranging between 200 and 1000 W/m², given that the temperature is constant at a value of 25^0.

Figure 4: Effect of irradiance on PV array performance at T = 25°C



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The equation (3) gives the power of solar panels

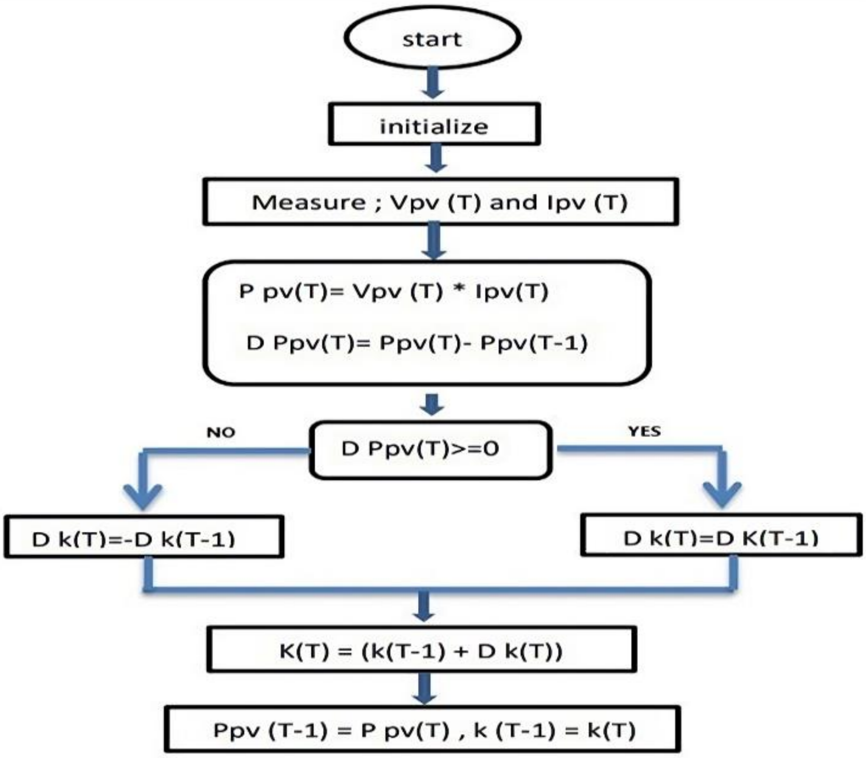
$$P_{pv} = V * I \quad (3)$$

Where (V) is the voltage between the terminals of the solar panels and (I) is the current that passes through them.

2.1.2 MPPT Algorithm

The P&O algorithm is widely used in MPPT due to its simple composition and high reliability. Works by jamming periodically so that it increases and reduces the end voltage and compares the output power to the previous turbulence capability [9]. Figure 5 below shows how this algorithm works

Figure 5: MPPT P&O algorithm flow chart



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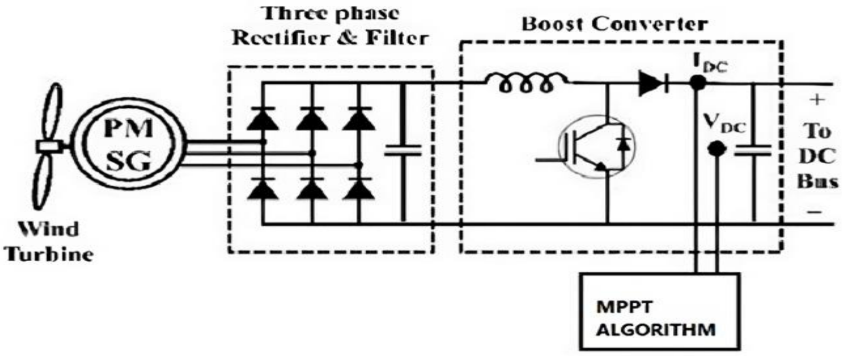
2.2 WIND ENERGY CONVERSION SYSTEM

The WECS system works by capturing the kinetic energy of the wind through specially designed turbines to rotate it. So that this turbine is connected to the generator (PMSG), which converts kinetic energy into electrical energy. This type of generator was chosen for its low cost and ease of maintenance. This produced energy is sent to the load or the network through several transformers, as shown in the figure. The diode is used to rectify the three-phase output of the generator. The voltage level is raised by a DC boost. [10]

Figure 6: Model of a WECS



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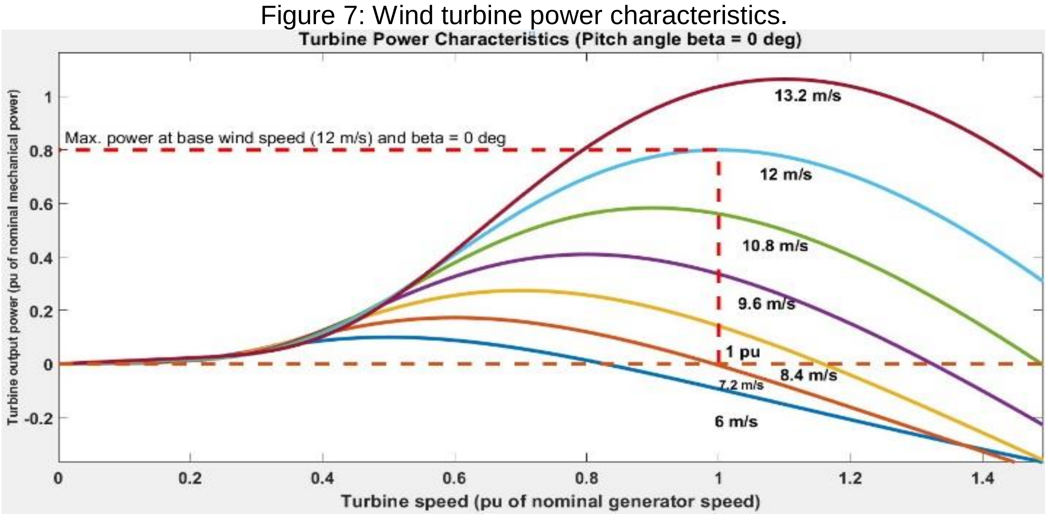
2.2.1 Formulation Method

Six The energy produced from wind turbines is given by the following equation. [11] [12].

$$P_w = \frac{1}{2}\pi\rho R^2 c_P(\beta \cdot \lambda)v^3 \quad (4)$$

ρ ; the air density
R^2; the radius of the wind turbine
c_P; the power coefficient
λ ; the tip-speed ratio
β ;the pitch angle
v^3;the wind speed

Figure 7: Wind turbine power characteristics.



Source: Authors.

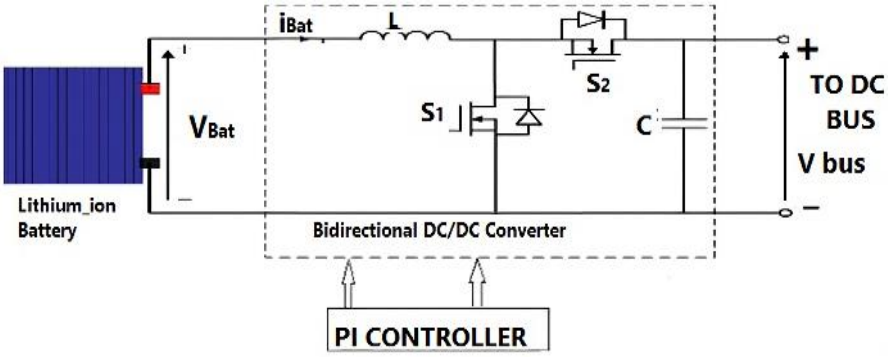
2.3 BATTERY ENERGY STORAGE SYSTEM WITH CONTROLLER

Due to the unpredictable nature of wind speed and solar radiation, the storage system is essential to maintaining the balance of energy flow at the load. In the proposed system, the (BSS) consists of a lithium battery and a bidirectional converter (DC-DC), and this converter is controlled by a control unit (PI), as Figure shows. [13]

The battery operates in two states, the charging state and the discharging state, and this is limited to the energy produced from renewable energy-generating sources (wind and sun) and there is another factor that is (SOC) that determines the energy restrictions. [13]

$$SOCmin \leq SOC \leq SOCmax \quad (5)$$

Figure 8: Battery energy storage system with bidirectional DC/DC converter



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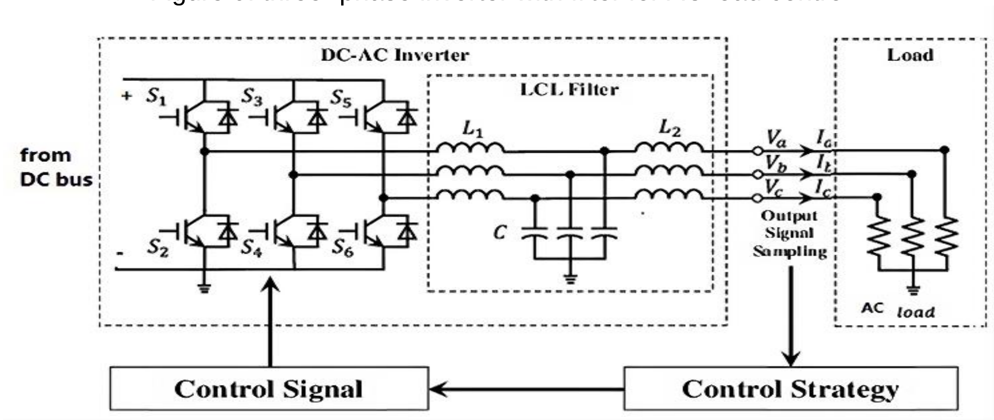
2.4 CONTROL OF THE AC LOAD

The DC bus is connected to a resistive load through a three-phase inverter equipped with a control unit, as shown in the figure (9). An LCL filter is used at the inverter output to filter out unwanted harmonic content. [14]

Figure 9: three- phase inverter with filter for AC load control



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3 ENERGY MANAGEMENT SYSTEM (EMS)

As per The energy management system coordinates the control of all procedures in this hybrid system. A photovoltaic system's DC-DC converter works in MPPT or out of MPPT mode. Wind power is controlled by a pitch angle controller. Depending on the balance and power limitations of the system, the dual battery adapter operates in both charge and discharge states. In order to maintain a constant voltage on the bus (DC). Under the different conditions of power generation from the two studied sources, the power flow must be balanced, and the power needed by the load must be ensured in all possibilities and circumstances. The following equation shows the energy balance. [15]

1.If. (p wind + p pv) > p load . and SOC < SOCmax

(P load + p battery) = (p wind + p pv) (6)

2.If. (p wind + p pv) > p load . and SOC > SOCmax

(P load + p battery) = (p wind + p pv .MPPT.OF) (7)

3.if. (p wind + p pv) < p laod and SOC > SOCmin

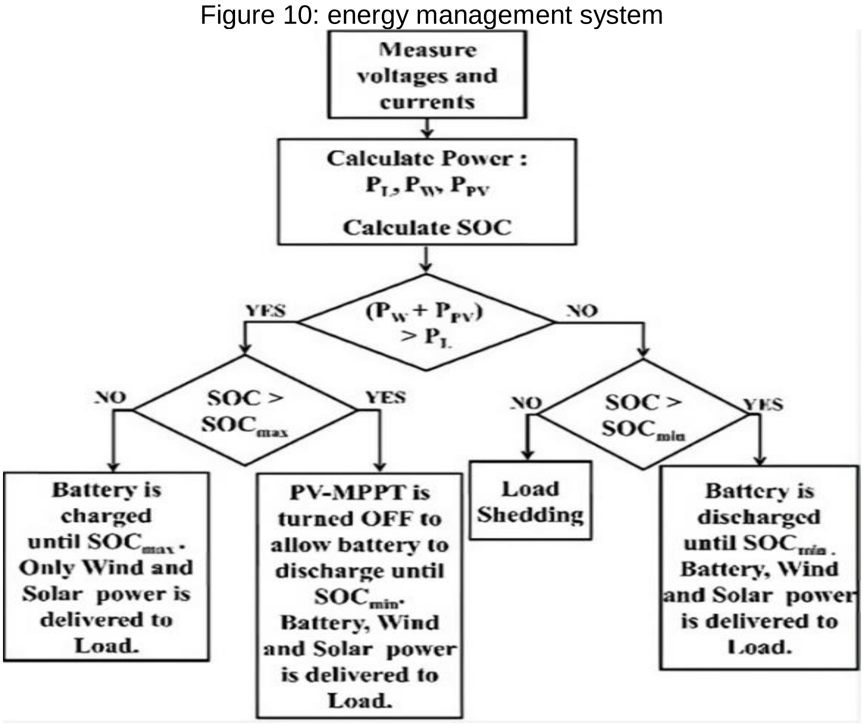
(P load) = (p battery + p wind + p pv) (8)

4.If . (p wind + p pv) < p laod and SOC < SOCmin

(P load) = (p wind + p pv) (9)

And the possibilities that we have depend on two conditions, the first is energy generation and the second is the state of the battery (SOC). If the energy generated from the sun and winds is greater than the required load, then the remaining energy is stored in the battery, and this is limited to the state of (SOC). If it is SOC max, the MPPT is turned off. To reduce the percentage of solar energy generation. If (max > SOC) the energy is stored in the battery. But if the generated power is less than the load. The battery will support the system and provide it with the energy it needs to meet the required load and maintain the balance of energy flow. This is provided that (SOC <SOCmin). [16]

Figure 10: energy management system



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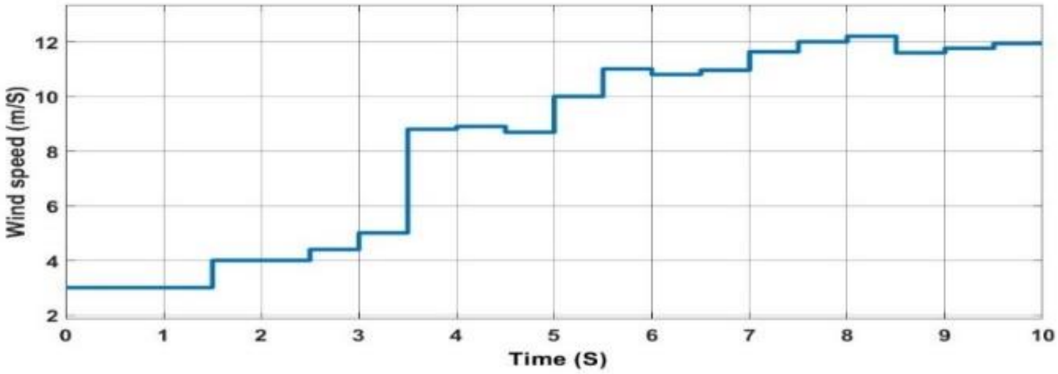
4 SIMULATION DIAGRAM AND RESULTS

For the proper and smooth management of this proposed system and to verify its efficiency. Numerical simulations were performed using Matlab to obtain data about the different weather conditions that this system may experience.

Figure 11: Wind speed



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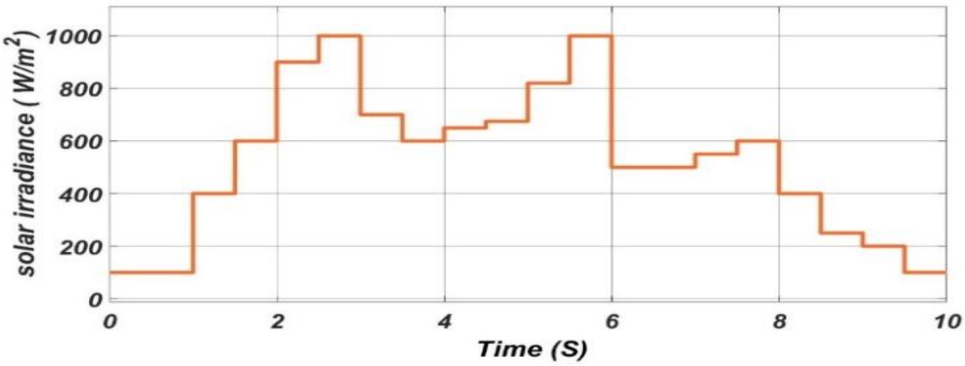
In the simulation shown in the figure (11), representing wind speed at different values, we can divide it into three stages. The first stage starts from the second 0 to the second 3.5; we can call it the very weak stage. Almost non-existent. Phase 2 starts from the end of the first stage to the second stage 6. We can describe it as a stage of medium speed value, where we note that the wind speed is between 8 m/s and 11 m/s. The last stage is where the wind speed is higher than in the other stages, where it is between 11 m/s and 12.2 m/s, and it can be said to be the ideal stage.

Figure 12: Solar irradiance



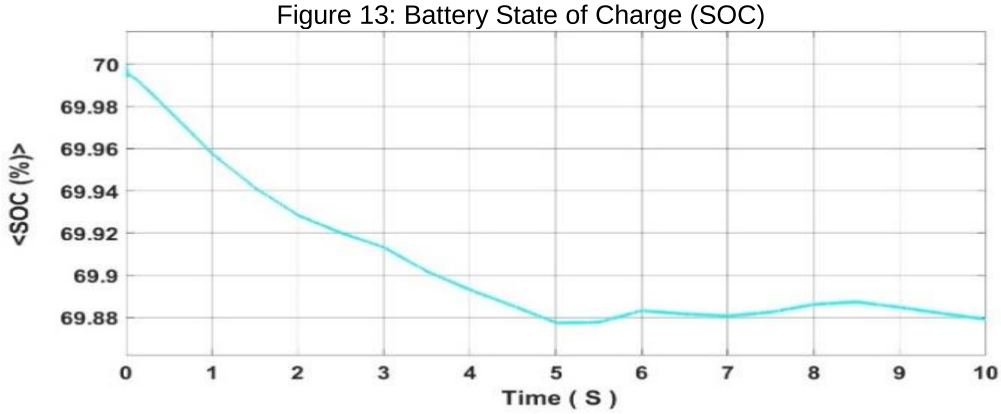
Source: Authors.

We see through the picture. Solar radiation data at different times. This curve can be divided into several stages. We notice from the drawing that from second 0 to second 1.5, the solar radiation is very weak, while in stage 2, it starts to rise from second 1.5 until it reaches its maximum value at second 3.5. Then in the third stage, it starts to decrease from the end of the previous stage until the second stage, where its value ranges between 600 W/m² and 700 W/m². Then it rises again to its maximum value of 1000 W/m² until the second 6, then decreases again until it reaches its weak value of 100 W/m².

4.2 INTERPRETATION AND DISCUSSION

The simulation results show that the strategy used in managing the system makes it possible to meet the energy needed by the load under different conditions of changes in solar radiation and wind speed. As shown in the pictures (14.15.16.17), the duration is between 0 and 1 second. The energy produced by the sun and wind is almost non-existent. However, the system was powered by battery power, so we note that the power needed by the load was provided. Then, from moments 1 to 3, we see that the solar panels are starting to produce more energy. We notice that the power of the supporting battery has started to decline relative to the increase in power produced by the solar panels. As for the period confined between 5 and 6 seconds, we notice that the battery started charging instead of discharging, and this is due to the fact that the energy produced from the wind and the sun is greater than what the load needs, and therefore the remaining energy is stored. At the moment, between 6 and 7 seconds, we notice a lethargy in battery power. Its stability in at point 0 because the energy produced is equal to the energy required for the load. Under different conditions and possibilities, the power at the inverter output will always provide what the load needs.

Figure 13: Battery State of Charge (SOC)



Source: Authors.

Figure 14: wind power

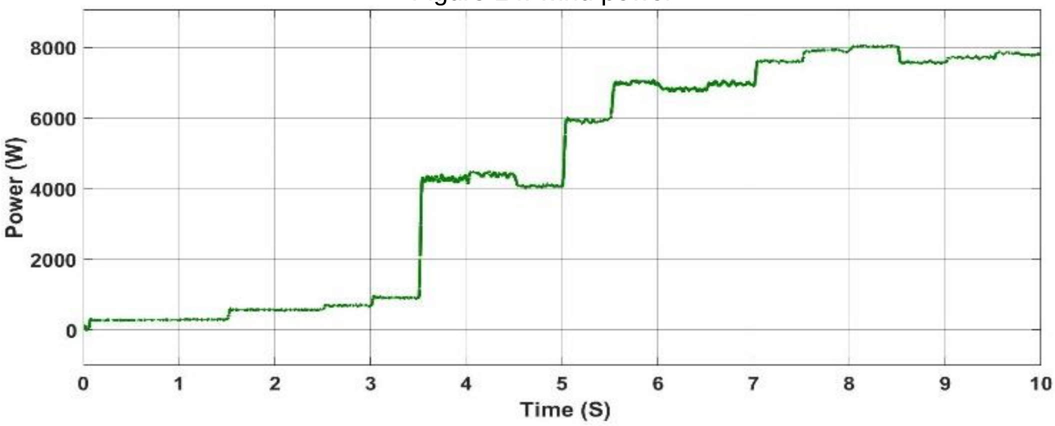


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Figure 15: Solar power

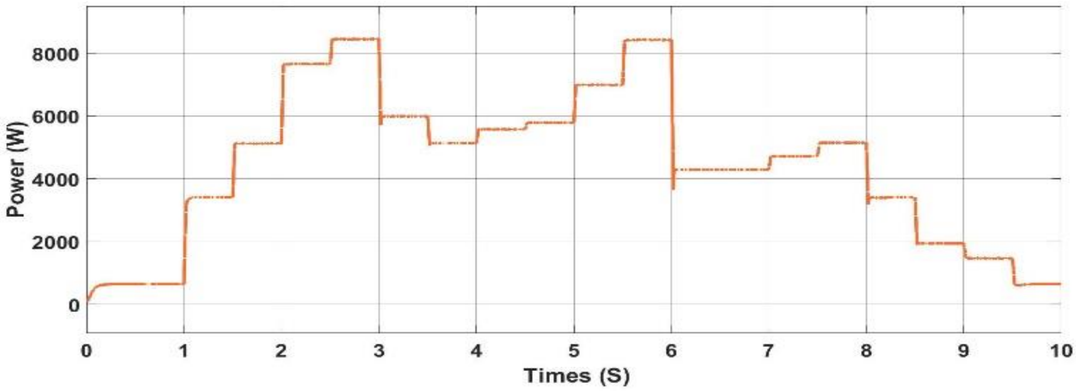

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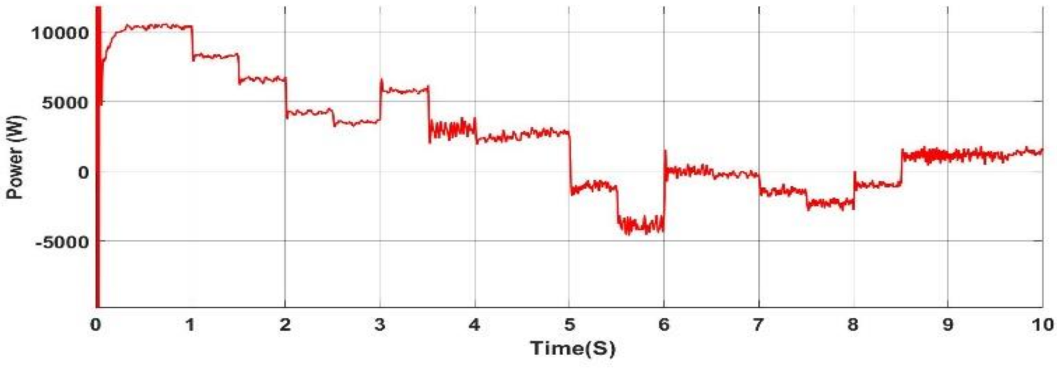
Figure 16: Battery power



Source: Authors.

Figure 17: Inverter and load demand power

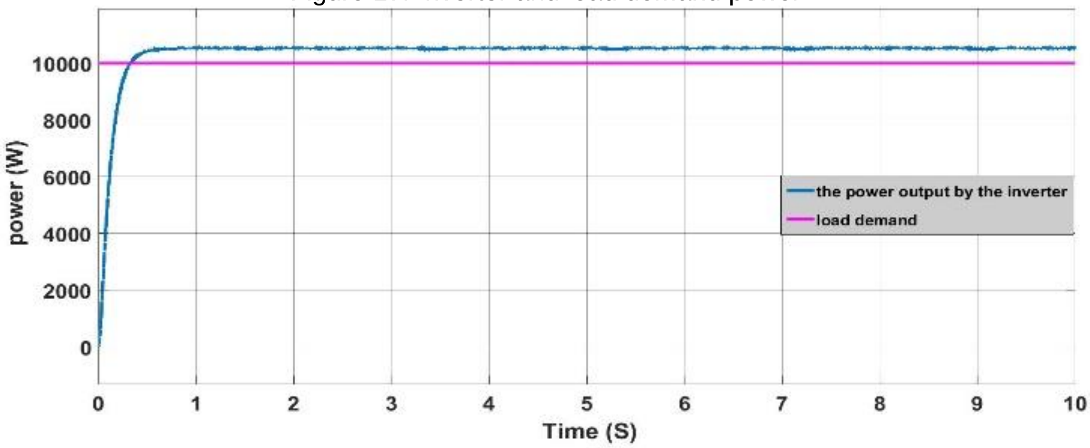


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Figure 18: Inverter voltage

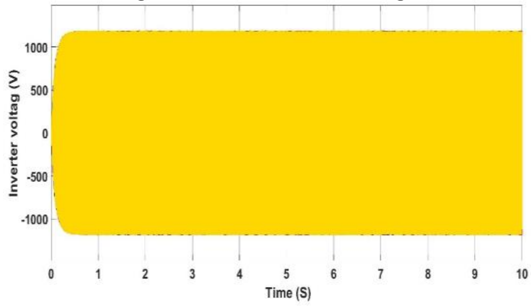

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Figure 19: Inverter current

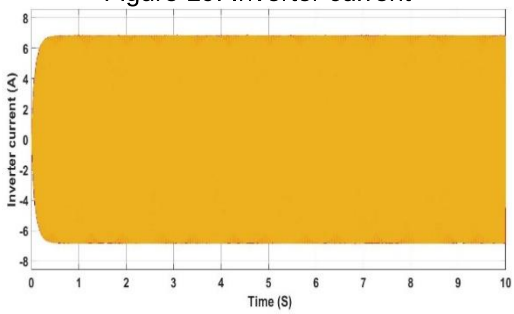

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Figure 20: Zom of Inverter voltage

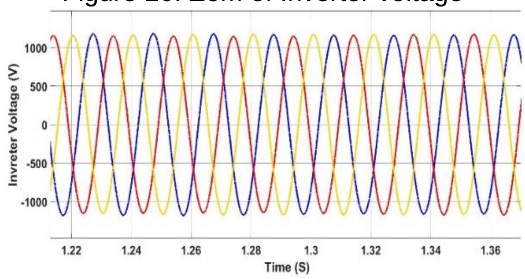

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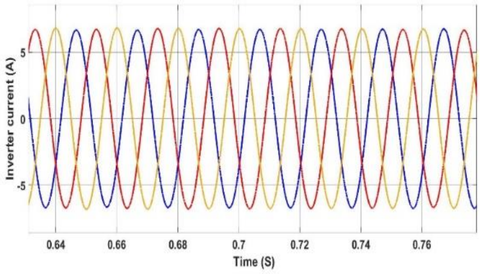
Figure 21: Zom of Inverter current



Source: Authors.

Table 1: Specification for the Hybrid System

System	**Parameters**
photovoltaic panels	Nominal power 214 W Current at maximum power IMPP 7.35A Open circuit voltage, Vco 36.3 V Short-circuit current Ic 7.84 A Maximum power voltage VMPP 29 V Parallel strings ;8 modules Series-connected modules per string; 5 modules
Boost converter	C = 0.91 mF, L= 6.6 mH
Battery	Nominal voltage (V) 220 V Rated capacity (Ah) 48 Ah
PMSG	Pn=8.4 Kw, Tn=76 N.m, p=4, Rs=0.5Ω, Stator dq-axis inductance Ld = Lq = 0.0082 H, Tf=0.433 Wb

Source: Authors

5 CONCLUSIONS

In this work, a hybrid system based on renewable energies was designed and simulated. The main objective of this work is to manage a hybrid system based on solar energy and wind energy in order to provide the permanent and continuous energy needed by the load under various weather conditions. Based on the results of the simulation shown, which showed the proper performance and reliability of feeding the load with the required energy, it can be said that the strategy of the proposal has been implemented. From this platform, it is possible to recommend the work of such systems to preserve the environment, as they can be exploited in rural and isolated areas.

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